Process Evaluation Section

Development and Validation of a Coupled Combustion Space/Glass Bath CFD Furnace Model

Problem/Opportunity

Competitive and regulatory pressures are motivating glass manufacturers to seek new ways to improve productivity, while reducing furnace energy use and emissions. The pursuit of these goals, however, often leads to conflicting requirements for the design and operational parameters of glass melting furnaces. To meet these conflicting requirements, a robust, validated, Computational Fluid Dynamic (CFD) model of glass melting furnaces is needed. The model will provide the industry with an analytical tool to evaluate new furnace designs, measure furnace performance, develop optimal fuel-firing strategies, and devise methods to improve cost efficiency and environmental performance.

Approach

ANL worked to develop of a "state-of-the-art" glass furnace model through a cost-sharing program with the following consortium of glass companies and universities: Techneglas, Libbey Inc., Visteon, Osram Sylvania, Owens Corning, Purdue University, and Mississippi State University. The three-diminsional CFD furnace model couples the combustion space with the glass batch and the glass melt through a rigorous radiation model that solves the spectral radiation transport equation in cartesian coordinates throughout the furnace volume. The model has been validated by using data obtained from in-situ measurements in operating glass furnaces. The new model couples and simulates all components of a glass melting furnace.

Results

ANL has developed the CFD models of the combustion space and glass melt. The combustion space model includes detailed reaction kinetics, a hybrid flow-kinetics calculation routine, interface heat and mass transfer, and pollutant formation and transport. The glass melt portion of the model has multiphase (solid, gas, and liquid) flow capability. A batch model has been incorporated directly into the glass melt calculation, allowing the computation of glass batch coverage. A rigorous spectral radiation model was developed to couple the glass melt and combustion space model into an overall furnace model.

Future Plans

The CFD furnace model is being further developed in Phase II. The key objectives of Phase II currently being worked on are (1) incorporate reduced glass chemistry models into the glass melt to compute/track key solid, gas, and liquid species; (2) develop/incorporate chemistry models to compute gaseous species production, bubble nucleation and growth, dissolution, and release from the glass melt surface (foaming); (3) develop/incorporate

chemistry and nucleation models of particulate formation for the gases emanating from the glass melt into the combustion space; (4) develop/incorporate glass quality indices into the simulation to facilitate optimization studies of productivity, energy use, and emissions; (5) create and validate furnace simulations of various furnace types; and (6) have industry participants evaluate the code by functioning as beta test sites.